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2 July 1980

USSR Report

ELECTRONICS AND ELECTRICAL ENGINEERING

(FOUO 12/80)

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USSR REPORT
ELECTRONICS AND ELECTRICAL ENGINEERING
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CONTENTS

ANTENNAS

- New Possibilities in the Optimization of the Characteristics
of Antenna Arrays..... 1

CERTAIN ASPECTS OF ASTRONOMY, SATELLITES AND SPACE VEHICLES

- Estimate of the Pointing Accuracy of a Telescope in an
Azimuthal Mount..... 6

COMPONENTS AND CIRCUIT ELEMENTS, INCLUDING WAVEGUIDES, CAVITY
RESONATORS AND FILTERS

- Digital Computer Simulation of a Nonlinear Tracking
Filter During Measurement of Poisson Processes..... 10

OPTOELECTRONICS, QUASI-OPTICAL DEVICES

- On Selection of Materials for Multichannel Acoustooptical
Processors..... 16

- High-Voltage Axially Symmetric Electron-Optical System With
Centrifugal Electrostatic Formation and Deep Retardation
of Electrons..... 20

PUBLICATIONS, INCLUDING COLLECTIONS OF ABSTRACTS

- New Electric Control and Automation Equipment Described..... 27
New Electronic Engineering Materials and Devices Presented.... 30
New Uses for Strong Electric Fields in Technology..... 33

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ANTENNAS

UDC 621.396.677.494

NEW POSSIBILITIES IN THE OPTIMIZATION OF THE CHARACTERISTICS OF ANTENNA ARRAYS

Moscow RADIOTEKHNIKA I ELEKTRONIKA in Russian No 3, 1980 pp 641-643

[Article by V. A. Pavlyuk, M. A. Martynov, and Ye. F. Krivosheyev, manuscript received 25 Aug 78]

[Text] This work gives an evaluation of an essentially possible level of an increase in the gain factor, absolute sensitivity, and permissible radiation power of antenna arrays when utilizing the peculiarities of the superconductive state of the substance and optimal current distributions found in compromise optimization of radio engineering parameters of discrete antennas. Theoretical and experimental results obtained by the authors were used as the initial information about the characteristics of normal and superconductive elements of such devices.

As is known [1], for a discrete system of M identical elements with radiation resistances R_{Σ} , losses R_0 , and power directivity pattern $q(\vec{u})$, considering that complex currents i_m and radius vectors of positions \vec{r}_m are subjected to statistically independent random errors with a normal distribution law, the averaged gain factor in a selected direction has the form of

$$G(l) = q(\vec{u}_0) \frac{|(l, l^0)|^2 + \gamma(l, l)}{(Hl, l) + \delta(l, l)}.$$

Here, $(l, l^0) = \sum_{m=1}^M i_m l_m^{*2}$ - scalar product of vectors $l = (l_1, \dots, l_M)$ and $l^0 = (\exp(-jk\vec{r}_1\vec{u}_0),$

$\dots, \exp(-jk\vec{r}_M\vec{u}_0))$ in an M -dimensional space characterizing rated exciting currents and the geometry of the systems; H -matrix of "mutual resistances";

$\gamma = (1 + \sigma_a^2) \exp(k^2 \sigma_p^2 + \sigma_\phi^2) - 1$ -- total variance defined by error variances in the amplitude σ_a^2 , phase σ_ϕ^2 and arrangement σ_p^2 ;

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$$\delta = \frac{1}{4\pi} \int_{\Omega} q(\vec{u}) d\Omega \left[\gamma + \frac{R_n}{R_x} (1 + \gamma) \right]; \quad k = \frac{2\pi}{\lambda}.$$

The vector of currents found by the variational method which maximizes the functional $G(i)$ satisfies the equation

$$i = \left[H + \left(\delta - \frac{\gamma}{(L, l^0)} \right) E \right]^{-1} l^0, \quad (1)$$

where E is a unit matrix.

It follows from (1) that, if we use the formulation of the problem of synthesis, there appears an addition in the diagonal elements of the matrix of mutual resistances: a parameter of regularization [2]. In this case, it has a simple physical meaning connected with the stochastic nature of processes, losses of energy in the antenna, and, as calculations showed, it leads to stable current distributions even if the distances between the elements are smaller than $\lambda/2$.

The solution (1) was achieved on an electronic computer by a one-step iteration method with an accuracy of 10^{-4} . For an initial approximation, we selected a linear equation $i = [H + \delta E]^{-1} l^0$ solved by the Gaussian method with selection of the main element in the column.

In the numerical studies of the characteristics of the antenna array in determining the quality factors of the elements and their efficiency in a normal η_{Cu}^{300K} or superconducting $\eta_{Pb}^{4.2K}$ state as functions of the effective length l_{eff} and the quality factor of the controls, the following evaluations of the losses in the radiator R_L with the length of the wire l and antenna circuit R_j in relation to the radiation resistance were used:

$$R_L/R_r = 0.86 \cdot 10^{-4} |R_L L_\alpha (2r)^{-1}, \quad (2)$$

$$R_j/R_r = 2.5 \cdot 10^{-4} |X_{a\alpha}|^{1+\alpha} L_\alpha Q_j (\omega C_M)^{-1}. \quad (3)$$

Here, $L_\alpha = (2N^2)^\alpha (\lambda/l)^{2\alpha+2}$, where the case of $\alpha = 0$ corresponds to an electric monopole, and $\alpha = 1$ corresponds to a loop-type N -turn radiator with the wire perimeter $l \leq 0.25\lambda$; $2r$ is the diameter of the wire; $X_{a\alpha}$ -- reactive part of the input resistance; C_M -- insulation capacitance; Q_j -- quality factor of the parts of the circuit which, at $j = 0$, corresponds to the quality factor of the controls Q_M , and, at $j = 1$, corresponds to the quality factor of insulation Q_M ; R_s -- surface resistance of the materials whose value for superconducting lead is taken from [3]. Expressions (2) and (3) are obtained by generalizing the known results [4] with consideration for the losses in the radiator, controls, and dielectrics. The values of

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G_r found in this way are in agreement with their measured values known at the present time which are shown in Figure 1 and those obtained on superconducting lead and niobium radiators operating in radio-frequency transmissive cryostats at a temperature of liquid helium [5-8].

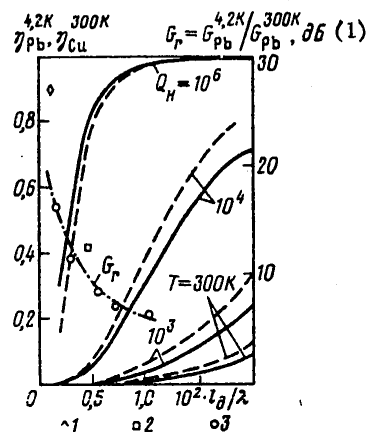


Figure 1. Calculated values of the efficiency (solid and dashed curves) and relative gain factor (dot-dash curves) as functions of the effective length and quality factor of the controls for the characteristics of the circuit given in [4] for the room and helium temperatures: 1 -- G. B. Walker et al (400 MHz), 1969; 2 -- S. Adachi et al (300 MHz), 1976; 3 -- circular frame antenna; dashed line -- asymmetrical spike.

Key: 1. dB

The use of the data for single radiators in calculating the characteristics of a linear equally spaced array with axial radiation from the frames makes it possible to determine optimal distances between the elements d_{opt}/λ on which it is possible to achieve a maximum increase in the gain factor G_r through the use of superconductivity and the mode of optimal currents. Figure 2 shows the dependence of G_r and d_{opt}/λ on the perimeter l of a single-turn loop (solid curves) and the number of turns of the radiator with $l = \lambda/4$ (dashed curves) for arrays of $2 \leq M \leq 15$ elements. There is an analogous behavior pattern of the dependences showing an increase in the absolute sensitivity of the array

$$E_r = \frac{E_{Cu}^{4.2K}}{E_{Pb}^{300K}} = \sqrt{\frac{P_{m}^{300K} G_{Pb}^{4.2K}}{P_{m}^{4.2K} G_{Cu}^{300K}}}$$

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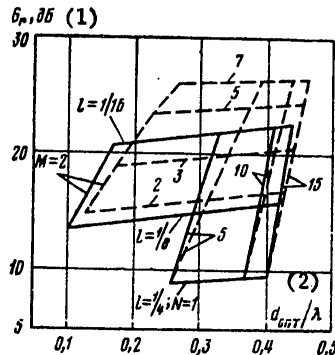


Figure 2. Relative gain factor and optimal distances between the elements as functions of electrical dimensions of the elements and their number for an array with a maximum gain. $3\sigma_a = 5\%$, $3\sigma_\phi = 5^\circ$, $3\sigma_p = 0.3\%$; $f = 300$ MHz.

Key: 1. dB
2. Optimal

determined by the power of internal noise $P_{\text{ш}}$ in its passband. Calculations indicate that the maximum excess of E_r for the examined discrete systems can be 50-70 dB.

Consideration of the external noise of the antenna ($T_{\text{a}} = 100^\circ \text{K}$ [9]) and the noise of the best preselectors in a normal $T_{\text{np}} = 200^\circ \text{K}$ and cryogenic $T_{\text{np}} = 10^\circ \text{K}$ states [9] indicates that the use of the phenomenon of superconductivity leads to a decrease in the total noise to one quarter or one-seventh. Therefore, the gain in the real sensitivity of these devices is, basically, determined by the value $\sqrt{\frac{G_{\text{pb}}^4 \cdot K / G_{\text{Cu}}^{300 \text{K}}}{G_{\text{Cu}}}}$ and, according to Figure

2, amounts to 10-30 dB. Evaluations of the value of the maximum power of radiation showed that, in principle, it is possible to increase it by 40-50 dB due to the increase in the permissible current densities in the superconducting elements of the antenna.

The calculations of the characteristics of antenna elements performed in this work with consideration for the effect of losses in the radiator, antenna circuit and insulation which are in agreement with the experimental data and the introduction of the synthesis of stochastic processes and power losses utilized in the formulation of the problem make it possible to state that the obtained results are close to realistically attainable results.

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CERTAIN ASPECTS OF ASTRONOMY, SATELLITES AND SPACE VEHICLES

UDC 522.983.1

ESTIMATE OF THE POINTING ACCURACY OF A TELESCOPE IN AN AZIMUTHAL MOUNT

Moscow IZMERITEL'NAYA TEKHNIKA in Russian No 1, Jan 80 pp 14-15

[Article by V. G. Shitov]

[Text] Because of design considerations, the widely used equatorial telescope mount is sometimes replaced by an azimuthal mounting comprised of two mutually perpendicular axles, one of which is vertical. These mounts are used on radiotelescopes with a wide-diameter dish [Ref. 1, 2], and also in large optical telescopes [Ref. 3]. However, the azimuthal mount considerably complicates the system for automatic control of telescope motion. In particular, the automatic control system must contain a converter for changing from the equatorial to the azimuthal coordinate system.

Conversion from the equatorial to the azimuthal coordinate system is done in accordance with equations that are readily derived from formulas of spherical trigonometry [Ref. 4]:

$$A = \arctg \frac{\cos \delta \sin t}{\sin \phi \cos \delta \cos t - \cos \phi \sin \delta} \quad (1)$$

$$z = \arccos (\sin \phi \sin \delta + \cos \phi \cos \delta \cos t), \quad (2)$$

where A, z are the azimuth and the zenith distance of the object in the azimuthal coordinate system; ϕ is the latitude where the telescope is set up; δ , t are the declination and hour angle of the object given in the equatorial coordinate system.

Expressions (1) and (2) imply that telescope motion with respect to both axes is nonuniform and alternating as the object is tracked. Because of severe requirements on the admissible error in training a telescope on an object, it is desirable to know how sensitive the azimuth and zenith distance are to various factors.

Three major components can be distinguished in the error: astronomical errors, instrument errors, and errors of the automatic control system.

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Astronomical errors are those due to inaccuracy in determining the coordinates of location of the facility, and inaccuracy of assignment of the coordinates of the object in the equatorial system. Instrument errors are those due to errors in setting the vertical axis of the telescope, and deviation from the perpendicular between the horizontal and vertical axis, and between the optical and horizontal axis. Errors of the automatic control system are made up of errors in calculating the instantaneous values of the coordinates, and errors in processing these calculated values.

Since analysis of the influence of errors of the automatic control system presupposes knowledge of the specific design, and known instrument errors may be very small or accounted for during coordinate conversion, we will restrict ourselves to examining only astronomical errors. We write the error with respect to azimuth as follows:

$$\Delta A = S_{\phi}^A \Delta \phi + S_{\delta}^A \Delta \delta + S_t^A \Delta t, \quad (3)$$

where $\Delta \phi$, $\Delta \delta$, Δt are errors with respect to latitude, declination and hour angle respectively, and S_{ϕ}^A , S_{δ}^A , S_t^A are functions of sensitivity of the azimuth to latitude, declination and hour angle.

Noting that (3) is the total differential of the function of the azimuth, we have

$$S_{\phi}^A = -\sin A \operatorname{ctg} z, \quad (4)$$

$$S_{\delta}^A = \frac{\cos \varphi \sin t}{\sin^2 z}, \quad (5)$$

$$S_t^A = \sin \varphi + \cos \varphi \cos A \operatorname{ctg} z. \quad (6)$$

We have introduced the sensitivity functions in non-normalized form since we were interested in absolute rather than relative errors. Graphs of sensitivity functions plotted from (4)-(6) for different declinations are shown in Fig. 1. Here and below, the latitude of the Crimean Astrophysical Observatory is taken as ϕ .

Similarly, for the error of zenith distance

$$\Delta z = S_{\phi}^z \Delta \phi + S_{\delta}^z \Delta \delta + S_t^z \Delta t,$$

where

$$\begin{aligned} S_{\phi}^z &= \cos A, \\ S_{\delta}^z &= \frac{\cos \varphi \sin \delta \cos t - \sin \varphi \cos \delta}{\sin z}, \\ S_t^z &= \frac{\cos \varphi \sin t \cos \delta}{\sin z}. \end{aligned}$$

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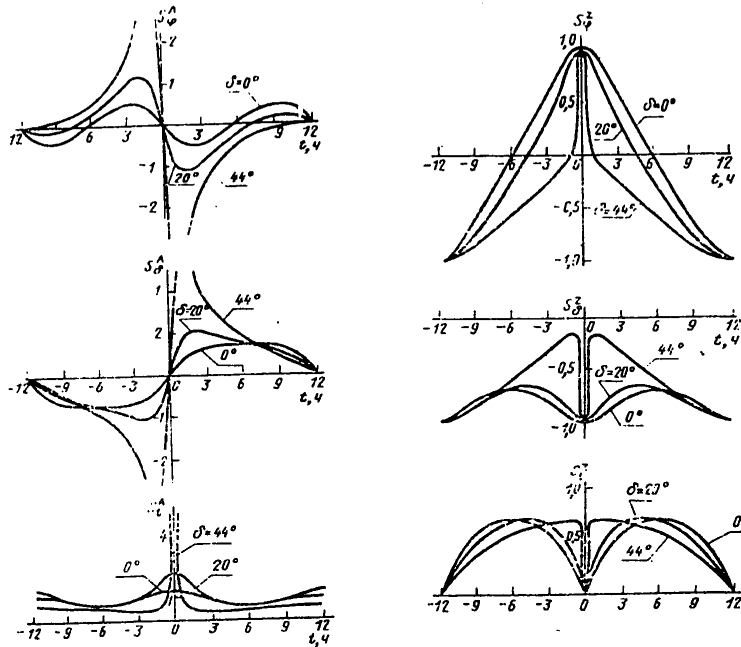


Fig. 2

Fig. 1

Graphs of these functions are shown in Fig. 2.

Let us determine the deviation of the optical axis of the telescope due to errors with respect to azimuth and zenith distance away from the true direction to the object. To do this, we consider the spherical triangle whose vertices are the zenith point, the true position of the object, and the point where the optical axis of the telescope intersects the celestial sphere. From the triangle it follows that

$$\cos x = \cos z \cos(z + \Delta z) + \sin z \sin(z + \Delta z) \cos \Delta A,$$

where x is the angular distance between the true direction to the object and the optical axis of the telescope. Let us call the sensitivity of the aiming error to astronomical errors the quantities

$$S_{\varphi}^x = \frac{x}{\Delta \varphi},$$

$$S_{\delta}^x = \frac{x}{\Delta \delta}, \quad (7)$$

$$S_t^x = \frac{x}{\Delta t}. \quad (8)$$

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The sensitivity of the aiming error to each of the astronomical errors is determined under condition that the other two errors are absent. A graph of the function of sensitivity of the aiming error to latitude is shown in Fig. 3 for different declinations.

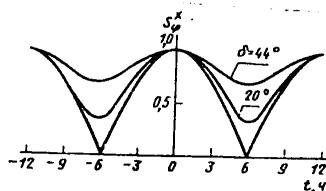


Fig. 3

Let us expand (7) and (8), using known relations of approximate calculations. For small Δz and ΔA

$$\cos(z + \Delta z) \approx \cos z - \Delta z \sin z,$$

$$\sin(z + \Delta z) \approx \sin z + \Delta z \cos z,$$

$$\cos \Delta A \approx 1 - \frac{(\Delta A)^2}{2}.$$

Considering these expressions, we find $S_\phi^x = 1$ and $S_\phi^y = \cos \delta$, which are in complete agreement with computer calculations done by (7) and (8), showing the applicability of the given assumptions.

Thus it can be concluded that despite a sharp increase in sensitivity of the azimuth to astronomical errors in the vicinity of the zenith, the sensitivity of the aiming error does not exceed unity over the whole celestial sphere. However, observations in the tracking mode in the vicinity of the zenith are nevertheless difficult because of the high azimuthal velocity (Fig. 1). Therefore more severe requirements with respect to accuracy in dynamics must be imposed on the drive of the azimuth axis. In addition, the drive of the azimuth axis must have a greater range of velocities than the drive of the zenith distance axis.

The results of calculations have been used in designing the large gamma telescope at the Crimean Astrophysical Observatory of the Academy of Sciences of the USSR.

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COMPONENTS AND CIRCUIT ELEMENTS, INCLUDING WAVEGUIDES,
CAVITY RESONATORS AND FILTERS

UDC 621.391.3:621.372.06:518.5

DIGITAL COMPUTER SIMULATION OF A NONLINEAR TRACKING FILTER DURING MEASUREMENT
OF POISSON PROCESSES

Moscow RADIOTEKHNIKA in Russian Vol 1 No 1, pp 53-56

[Article by A. N. Mart'yanov and V. G. Tatosenko, manuscript received 4
Apr 79]

[Text] I. By observations of the conditional Poisson process $N(t, \lambda)$, it is required, by the criterion of the minimum of the mean square of error (SKO), to evaluate the vectorial Markov process $x(t)$ satisfying the linear stochastic differential equation

$$dx(t) = \hat{F}x(t)dt + \hat{G}d\eta(t), \quad (1)$$

where \hat{F} and \hat{G} are the known matrix functions; $\eta(t)$ is the vectorial Wiener random process satisfying the Ito equation [1]. The intensity $\lambda(x)$ of the Poisson process $N\{t, \lambda(t, x)\}$ is a nonlinear function of $x(t)$ of the kind of

$$\lambda(t, x) = \Lambda \{1 + \alpha \cos [d^T x(t)]\}, \quad (2)$$

where $\alpha \leq 1$ -- dimensionless parameter; d^T -- transposed vector; Λ -- a certain constant.

In works [2, 4], the following differential equations were obtained for this problem which describe the procedure of finding a quasi-optimal evaluation -- $x^*(t)$

$$dx^*(t) = \hat{F}x^*(t)dt + \alpha \sin [d^T x^*(t)] \{1 + \alpha \cos [d^T x(t)]\}^{-1} \hat{D}^*(t) d\{dN(t) - \lambda(t, x^*)dt\},$$

$$x^*(t_0) = M\{x(t_0)\} \quad (3)$$

and a covariance matrix of errors

$$d\hat{D}^*(t) = \hat{F}\hat{D}^*(t)dt + \hat{D}^*(t)\hat{F}^Tdt + \hat{G}\hat{G}^Tdt + \hat{D}^*(t)d\{\Lambda \alpha \cos [d^T x^*(t)]\}d^T\hat{D}^*(t)dt -$$

$$- \Lambda \{\alpha + \cos [d^T x^*(t)]\} \{1 + \alpha \cos [d^T x^*(t)]\}^{-2} \hat{D}^*(t) d\hat{D}^*(t) dN(t), \quad \hat{D}^*(t_0) =$$

$$= \text{cov}\{x(t_0) - M\{x(t_0) - x^*(t_0)\} [x(t_0) - x^*(t_0)]^T\}, \quad (4)$$

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where $dN(t)$ -- increments of the Poisson process $N\{t, \lambda(t, x)\}$ in the time interval dt ; $M\{\cdot\}$ -- symbol of the operation of mathematical expectation.

Equations (3), (4) are nonlinear stochastic differential equations and cannot be solved by the analytic methods.

The accuracy characteristics of the class of nonlinear filters under study can be evaluated by using the methods of digital simulation. One of the possible approaches to the solution of this problem is explained below and some specific examples are examined.

II. If we change from differential to finite differences in (1), then we shall obtain a procedure for constructing the components of the vectorial process $x(t)$ [5]:

$$\begin{aligned} \Delta x(t_i) &= \hat{F}x(t_i) \Delta t + \hat{G} \Delta \eta(t_i); \\ x(t_i + \Delta t) &= x(t_i) + \Delta x(t_i); \quad x(t_0) = x_0. \end{aligned} \quad (5)$$

The increments of the Wiener process can be simulated by using the algorithm given in [6],

$$\Delta \eta(t_i) = \sqrt{N_0 \Delta t} n(t_i), \quad (6)$$

where N_0 -- spectral density of the process $u(t) = \frac{d\eta}{dt}$; $n(t_i)$ -- one of the numbers of the selection of a discrete normal random process with $M\{n(t_i)\} = 0$ and a single variance.

In accordance with the definition, $\Delta N(t)$ assumes only integral values and has the probability distribution function

$$P(k) = \frac{1}{k!} \exp \left[- \int_t^{t+\Delta t} \lambda(\tau, x) d\tau \right] \left[\int_t^{t+\Delta t} \lambda(\tau, x) d\tau \right]^k; \quad \Delta N = k. \quad (7)$$

The sequence of integral numbers adhering to the distribution (7) can be found by defining such a number k for which the following condition would be fulfilled [7]

$$\sum_{l=1}^{k+1} -\frac{1}{\Lambda} \ln(1 - R_l) > 1; \quad \Lambda = \int_t^{t+\Delta t} \lambda(\tau, x) d\tau, \quad (8)$$

where R_l -- one of the numbers distributed evenly in the interval $[0, 1]$.

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The integration step Δt in (5) should be selected as such at which the following condition is fulfilled with a sufficient degree of accuracy:

$$\lambda(\tau, x) \Big|_t^{t+\Delta t} \approx \text{const.} \quad (9)$$

The simulation of a nonlinear filter amounts to a simultaneous numerical solution of equations (3) and (4) with consideration of (5) and substitution in them of random numbers ΔN obtained as a result of simulation instead of $dN(t)$ at each step.

1. First let us examine the simplest case when $x(t)$ is a sum of a determined and a random components

$$x(t) = \omega t + \beta \chi(t), \quad (10)$$

where ω and β -- known constants; $\chi(t)$ -- one-dimensional Wiener process with the parameter R^{-1} satisfying the stochastic equation [1]

$d\chi(t) = R^{1/2} dw(t)$; $w(t)$ -- normalized Wiener process of the first order.

Under these conditions, the evaluation equation (filter equation) and the covariance matrix equation assume the following forms:

$$d\chi^*(t) = -\beta \alpha \sin[\omega t + \beta \chi^*(t)] \{1 + \alpha \cos[\omega t + \beta \chi^*(t)]\}^{-1} D^*(t) (dN(t) - \Lambda [1 + \alpha \cos[\omega t + \beta \chi^*(t)]] dt), \quad \chi^*(t_0) = M\{\chi(t_0)\}; \quad (11)$$

$$dD^*(t) = R^{-1} dt + D^{**}(t) \Lambda \alpha \beta \cos[\omega t - \beta \chi^*(t)] dt - \Lambda \beta^2 \{\alpha + \cos[\omega t + \beta \chi^*(t)]\} \times \\ \times \{1 + \alpha \cos[\omega t + \beta \chi^*(t)]\}^{-2} D^{**}(t) dN(t), \quad D^*(t_0) = M\{[\chi(t_0) - \chi^*(t_0)]^2\}. \quad (12)$$

If the condition $\omega \gg R^{-1}$ is fulfilled, then, by using the method proposed in [3, 8], it is possible to transform (12) into an ordinary Riccati equation whose solution for $t \geq 0$ has the following form

$$D^*(t) = \frac{D_0^* R^{-1} \Lambda [1 - (1 - \alpha^2)^{1/2}] + R^{-1} \text{th}\{[R^{-1} \Lambda (1 - (1 - \alpha^2)^{1/2})]^{1/2} t\}}{\{R^{-1} \Lambda [1 - (1 - \alpha^2)^{1/2}]^{1/2} + D_0^* \Lambda [1 - (1 - \alpha^2)^{1/2}] \text{th}\{[R^{-1} \Lambda (1 - (1 - \alpha^2)^{1/2})]^{1/2} t\}\}}. \quad (13)$$

Under steady-state conditions at $t \rightarrow \infty$

$$D^*(\infty) = \lim_{t \rightarrow \infty} D^*(t) = \left\{ R \frac{\Lambda}{\beta^2} [1 - (1 - \alpha^2)^{1/2}] \right\}^{1/2}.$$

The example examined above occurs in problems of the evaluation of the phase of a signal modulating the optical-frequency carrier with respect to intensity, and equation (11) describes the structure of a quasi-optimal nonlinear filter tracking the phase of the envelope of the optical-frequency carrier.

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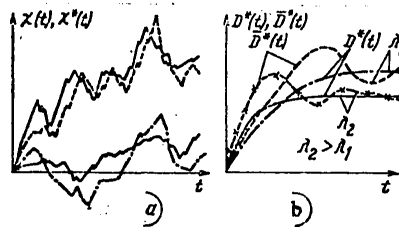


Figure 1

In order to check the correctness of the obtained approximations, we find the error variance $D^*(t)$ simultaneously from the solution of equation (13) and by averaging the set of the realization of the integral curves of equation (12) obtained through its simultaneous solution with (11) and simulation of processes $X(t)$ and $N(t)$.

In order to reduce the expenditure of the machine time, the integration step in equations (11) and (12) must be as large as possible. But, on the one hand, the integration step is determined by the condition (9) and on the other, according to Kotelnikov's theorem, the condition $\Delta t \leq \pi/\omega$ must be fulfilled. In practice, the following is selected

$$\Delta t \leq \frac{\pi}{5\omega} + \frac{\pi}{10\omega}. \quad (14)$$

Thus, the most rigid integration step Δt is determined from the conditions (9) or (14).

Figure 1a shows several models of the random process $X(t)$ and its evaluation $X^*(t)$ for different parameters of the intensity function $\lambda(t, X)$, and Figure 1b shows error variances of the evaluation $D^*(t)$ found by solving equation (13) and integral curves $\bar{D}^*(t)$ from equation (12). It can be seen that $D^*(t)$ can be considered as a mathematical expectation of $\bar{D}^*(t)$ models, which confirms the possibility of limiting oneself to the approximation (13) in studying this filter.

2. Let $X(t) = \int_0^t [u + v(\tau)] d\tau$ be represented in the form

$$X(t) = \int_0^t [u + v(\tau)] d\tau,$$

where $v(t)$ -- normal random process satisfying the equation

$$dv(t) = Fv(t)dt + \sigma d\eta(t), \quad (15)$$

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ω -- random value with a known distribution which can be described formally as $d\omega(t) = 0$.

In this case, vector $x(t)$ and matrix functions \hat{F} , \hat{G} and d in equation (1) and formula (2) assumed the following form

$$x(t) = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}, \quad \varphi(t) = \begin{bmatrix} \omega \\ \omega \\ v(t) \end{bmatrix}, \quad \hat{F} = \begin{bmatrix} 0 & 1 & 1 \\ 0 & 0 & 0 \\ 0 & 0 & F \end{bmatrix}, \quad \hat{G} = \begin{bmatrix} \hat{G}_1 & \hat{G}_2 \\ \hat{G}_3 & \hat{G}_4 \end{bmatrix}, \quad d = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}.$$

It is more convenient to represent the vector-matrix equations of evaluation (3) and covariance matrix (4) in the form of a system of scalar equations. This makes it possible to reduce the expenditure of the machine time, because, due to the symmetry of the covariance matrix, it is sufficient to solve $n(n-1)/2$ equations out of their total n^2 number. At the same time, the equations themselves become substantially simplified, because many of the elements of the matrices \hat{F} and \hat{G} are zero elements.

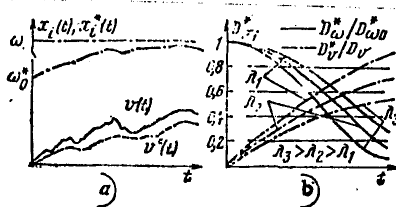


Figure 2

In the case in question, it is impossible to obtain equations for the elements of the covariance matrix which do not depend on the evaluation $x^*(t)$ and observed process $N\{t, \lambda(t, x)\}$, and the accuracy characteristics of the filter can be studied only by the simulation methods.

The sequence of operations at all stages of simulation coincides with that described in Part II of this article. A new point is the selection of the initial conditions during the integration of the equations of evaluation and the covariance matrix, since the behavior of the solution of a nonlinear differential equation depends substantially on the initial conditions.

The initial conditions for the components of the vector $k^*(t)$ can be determined from the relation $x^*(t_0) = M\{x(t_0)\}$.

If at the moment of time t_0 all components of the vector $x(t)$ are independent, then the elements of $D_{ij}^*(t_0)$ which characterize the correlation between x_i and x_j for $t = t_0$ can be taken to be equal to zero. In the absence of a priori information, the value of $D_{ij}^*(t_0)$ can be selected to be equal to the steady-state value of the variance $\sigma_i^2(\infty) = M\{[x_i(\infty) - M\{x_i(t)\}]^2\}$ of the

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corresponding component of $x(t)$. However, if there are a priori data making it possible to take $D_{ii}^*(t_0) < \sigma_i^2(\infty)$, then it will make it possible to reduce the time of the transition of curve $D^*i_i(t)$ to a steady-state solution.

Figure 2a shows the models of individual components and their evaluations of the vector $x(t)$ obtained for various parameters of the intensity function $\lambda(t, x)$ and matrices F and G , and Figure 2b shows the behavior of the evaluation error variance of the components ω and $v(t)$ and the vector $x(t)$.

It can be seen from the curves that the time of the transition to the mode of stable tracking, when errors assume a steady-state value, depends not only on the nature of the frequency fluctuations $v(t)$, but also on the mean value of λ of the intensity function of the observed Poisson process.

The variance curves were obtained by averaging with respect to the set of models of the integral curves of solutions of the equation of covariance matrix.

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OPTOELECTRONICS, QUASI-OPTICAL DEVICES

UDC 621.37/39:534

ON SELECTION OF MATERIALS FOR MULTICHANNEL ACOUSTOOPTICAL PROCESSORS

Moscow RADIOTEKHNIKA I ELEKTRONIKA in Russian, No 3, 1980 pp 654-656

[Article by V. V. Proklov, V. I. Mirgorodskiy, S. V. Peshin, G. N. Shkardin, and D. P. Kanayev; reported at the 10th All-Union Conference on Quantum Acoustics and Acoustoelectronics, Tashkent, May 1978. Manuscript received 18 Aug 78]

[Text] Multichannel acoustooptical processors (AOP) are promising devices for the input of signals into systems of optical information processing, particularly on intermediate frequencies of ~ 100 -300 MHz [1]. Of great interest is the increase of the informational capacity of the processed signals which can be characterized by the product (NBT_I) , where N is the number of identical channels, B and T_I are the width of the frequency band and the length of signals processed in one channel [2]. The obvious ways of solving this problem could be the increase of the broadbandness of the devices due to the widening of the relative passband and the physical volume of the optically processed signal determined by the selection of materials for acoustical lines with a low speed of sound and great length along the direction of its propagation. However, the improvement of AO [acoustooptical] devices by these means is substantially limited by the fact that, when the sound frequency increases over 100 MHz, the absorption of sounds increases considerably in most AO materials, and by the limitedness of the dimensions of real crystals L (usually $L \sim 5$ -15 cm). This makes it necessary to search for compromise solutions in the development of AOP, which requires to use an algorithmized approach to the selection of structures and materials used.

In order to determine the possible maximum values of the product (NBT_I) , it is necessary to keep in mind the following relations:

1) the connection of the maximum length of the signal T_I with the length of the crystal L

$$T_I = L/v_s \quad (1)$$

where v_s is the speed of sound;

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2) the connection of the passband B with the central frequency f_0

$$B = a f_0, \quad (2)$$

where a depends on the broadbandness of the piezoelectric sound converter and on the matching of the light and sound fronts (usually $a \leq 0.3$);

3) limitation of the maximal useful length of the crystal L due to the absorption of sound in the material of the acoustic line

$$\alpha L \leq b, \quad (3)$$

where the value of b depends on the concrete purpose of the AOP, but usually $1 \leq b \leq 2$. Taking into consideration that in the majority of crystalline materials at frequencies over 100 MHz the absorption of sound grows quadratically with a frequency of $\alpha = \alpha_0 f^2$, we shall obtain from (1)-(3)

$$f_{\text{out}} = \gamma b / \alpha_0 L, \quad (4)$$

$$(BT_1)_{\text{max}} = \frac{aL}{v_s} f_{\text{out}}. \quad (5)$$

In the case of multichannel AOP, an important parameter is the density of the arrangement of channels in the crystal. On the one hand, the more channels can be formed, the greater the resulting $(NB T_1)$, and on the other, the density of the arrangement of channels is limited by the permissible degree of channel overlapping.

In order to evaluate diffraction overlapping of sound beams in adjacent channels situated on the plane (xy) of the end of the crystal at the distance d from one another, it is necessary to calculate the sound field in the crystal. In the approximation of the Fraunhofer diffraction, the area of the overlapping of acoustic beams in two adjacent channels is expressed by the relation [3]

$$\Phi \approx \frac{(2\beta - d)^2}{4\beta} L, \quad (6)$$

here, β is the height of the overlapping of two adjacent channels at the end of the crystal, from which we shall obtain the following for d_{min} and a_{min} ensuring the highest degree of compactness of the channels in the given crystal:

$$d_{\text{min}} \approx \sqrt{\frac{4L}{k} (2 - \sqrt{3}\gamma)}, \quad (7)$$

$$a_{\text{min}} \approx \sqrt{\frac{4L}{k} \left(1 - \frac{1}{6} \sqrt{3}\gamma\right)}, \quad (8)$$

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where $\gamma \ll 1$ is the relative overlapping of adjacent beams, a is the height of the converter, and k is the wave vector of sound. The value of N_{\max} with the cross dimension Y_0 determined from (7) and (8) is

$$N_{\max} = \frac{Y_0}{a_{\text{МНН}} + d_{\text{МНН}}} \quad (9)$$

(1) Материал	(2) Тип акустической волны	(3) Скорость звука v_s (10^5 см/сек)	(4) Поглощение звука $\alpha_{100 \text{ МГц}}$ (дБ/см)	(5) Длина кристалла L (см)	(6) Ширина кристалла H (см)	(7) Оптимальная частота звука $f_{\text{опт}}$ (МГц)	(8) $(BT_I)_{\max}$	(9) N_{\max}	(10) $(NBT_I)_{\max}$
$\text{Bi}_{12}\text{GeO}_{20}$	сдвиг.	1,77	$25 \cdot 10^{-3}$	10	2,0	590	10 000	32	320 000
LiNbO_3	прод. 12	6,57	$2 \cdot 10^{-3}$	5	2,0	2950	6735	51	343 485
$\alpha\text{-HfO}_3$	прод.	2,89	$\sim 1 \cdot 10^{-1}$	10	10	294	3050	125	381 250
PbMoO_4	прод.	3,75	$\sim 1 \cdot 10^{-1}$	6	2,0	380	1825	31	56 575
TeO_2	сдвиг.	0,62	~ 3	3	1,0	98	1420	27	38 340

- Key: 1. Material
 2. Type of acoustic wave
 3. Speed of sound, v_s (10^5 cm/sec)
 4. Sound absorption, $\alpha_{100 \text{ MHz}}$ (dB/cm)
 5. Length of crystal L (cm)
 6. Width of crystal H (cm)
 7. Optimal sound frequency f_{opt} (MHz)
 8. $(BT_I)_{\max}$
 9. N_{\max}
 10. $(NBT_I)_{\max}$
 11. Displacive
 12. Longitudinal

We used (4), (5), (7)-(9) in calculating optimal parameters of multichannel AOP for various materials which ensure a sufficiently high effectiveness of diffraction and at the present time are produced by the methods of industrial technology with satisfactory dimensions and quality. The results of the calculations are summarized in the table. In our calculations, it was assumed that $a \approx 0.3$; $b \approx 2$; $\gamma \approx 0.1$. It can be seen from the table that the most promising for multichannel AOP are single crystals of bismuth germanate $\text{Bi}_{12}\text{GeO}_{20}$, α -iodic acid $\alpha\text{-HfO}_3$ and lithium niobate LiNbO_3 . It should be mentioned that the optimal working conditions of multichannel AOP using LiNbO_3 with which a maximum (NBT_I) is achieved are at a very high frequency ($f_{\text{opt}} = 2950 \text{ MHz}$), as a result of which there may occur difficulties in the generation of a powerful sound, electrical insulation of adjacent channels, etc. When using $\alpha\text{-HfO}_3$, there arise difficulties connected with the protection of optical surfaces of the crystals against atmospheric influences and the technological complexity of producing an excessively large number of channels ($N_{\max} = 125$). On the basis of the above, bismuth

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germanate, for which $(BT_I) = 10,000$ and $(NBT_I) = 320,000!!$ on a relatively low frequency of ~ 590 MHz, is of particular interest for the creation of multichannel AOP.

The experiments and analysis indicate that $Bi_{12}GeO_{20}$ is at the present time most promising in multichannel AOP on frequencies over 100 MHz.

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HIGH-VOLTAGE AXIALLY SYMMETRIC ELECTRON-OPTICAL SYSTEM WITH CENTRIFUGAL
ELECTROSTATIC FORMATION AND DEEP RETARDATION OF ELECTRONS

Moscow RADIOTEKHNIKA I ELECTRONIKA in Russian No 3, 1980 pp 623-627

[Article by L. I. Andrikanis and N. S. Bunina, manuscript received 14 Mar 79]

[Text] The authors present the results of their calculations of a high-voltage axially symmetric electron-optical system with centrifugal electrostatic formation and deep retardation of electrons (high-voltage gap 8 cm, depth of electron retardation $\varphi_a / \varphi_{col} = 5$, perveance with respect to the potential of the collector $P = (240-345) \cdot 10^{-6} \text{ A/V}^{3/2}$).

The method of centrifugal electrostatic formation of electron streams (TsEF) [1] made it possible to develop a number of electron-optical systems (EOS) ensuring a deep retardation of intensive divergent extended electron beams [1-4]. These systems are intended for use in high-voltage electron-beam switching devices.

EOS ensuring a heavy current, a small drop of the voltage in the device during the passage of the current, and high values of voltage when the current is switched off are of practical interest for the electron-ray switch. In application to EOS, these requirements mean high values of the perveance calculated by the potential of the accelerating anode and the collector, deep retardation of electrons in the area adjacent to the collector, and large values of the high-voltage gap.

Earlier, works [2, 3] examined axially symmetric EOS with TsEF calculated for the value of the switched voltage $U_{switched} = 50 \text{ kV}$, which corresponds to the length of a high-voltage gap $L_{gap} = 1 \text{ cm}$. This work gives the results of the calculations of EOS with a high-voltage gap of $L_{gap} = 8 \text{ cm}$. According to preliminary evaluations, this will make it possible to make calculations for the switching of a voltage with an amplitude of the order of 400 kV. Calculations of a high-voltage EOS with TsEF were done according to the KSI-BESM-6 program developed by I. M. Bleyvas et al [5].

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The diagram of the axially symmetric EOS with TsEF is shown in Figure 1. An intensive divergent electron beam (1) leaves the cylindrical cathode (2), is accelerated by the anode (3), and then moves in the retarding field of the collector (4) and the forming electrode near the collector (5). During the passage of the electron stream, the forming electrodes (6, 7) have the potential of the cathode. When the high switched voltage U_{switched} is delivered to the collector, these electrodes, the anode, and the modulator (8) receive a negative cutoff voltage.

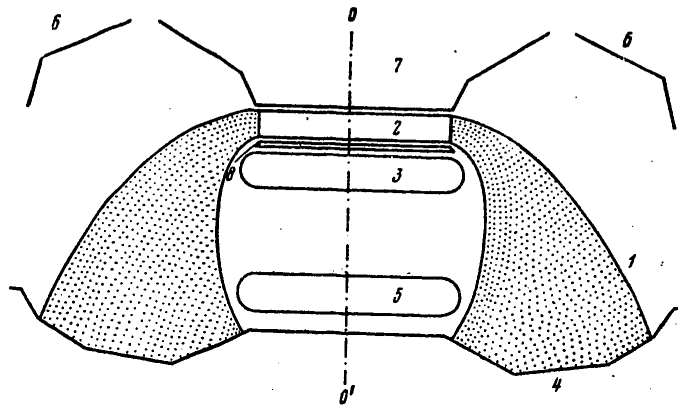


Figure 1. Diagram of an Axially Symmetric Electron-Optical System: 1 -- electron beam; 2 -- cathode; 3 -- anode; 4 -- collector; 5 -- forming electrode near the collector; 6, 7 -- forming electrodes; 8 -- modulator. 00' -- rotation axis.

The diameter of the cathode of this system is 200 mm, and the height of the emitting surface is 28 mm. The distribution of the potentials on the electrodes under the cutoff conditions is such that the high-voltage gap is determined by the distance between the collector and the anode, as well as between the collector and the forming electrode (6).

The results of a numerical analysis of the EOS are shown in Figures 2, 3. The distribution of the electric field in the system and the trajectories of electrons are given for two values of the potential of the collector $\varphi_{\text{col}} = 0.2$ and $0.1 \varphi_a$, i.e., the calculations were done for the conditions of energy recuperation on the collector and deep retardation of electrons in the area adjacent to the collector. A good level of current passage is maintained in the system: at $\varphi_{\text{col}} = 0.2 \varphi_a$, more than 95% of the cathode current I_{cath} passes to the collector and the forming electrode near the collector.

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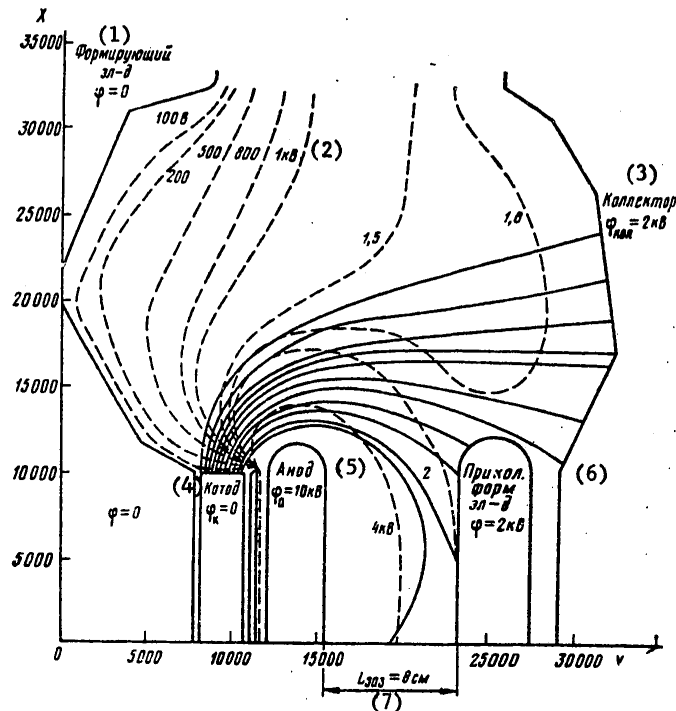


Figure 2. Results of the Computation of the EOS on an Electronic Digital Computer. Solid curves -- trajectories of the stream tubes; dashed curves -- equipotentials. OY -- rotation axis.

Key: 1. Forming electrode 5. Anode
 2. kV 6. Forming electrode near the collector
 3. Collector
 4. Cathode 7. Gap

Systems with TsEF forming divergent curvilinear electron streams, as a rule, have a nonuniform distribution of the current density along the entire length of the beam from the cathode to the collector. For example, in this system, the ratio of current densities for $\varphi_{col} = 0.2 \varphi_a$ calculated for the extreme stream tubes is $j_{20}/j_1 \approx 20$. However, this does not prevent obtaining large values of perveance in this system. The perveance of the EOS calculated by the anode potential is $P_a = 21.6 \cdot 10^{-6} \text{ A/B}^{3/2}$. The perveance of the system with consideration for the retardation of electrons calculated by the potential of the collector $P_{col} = 240 \cdot 10^{-6} \text{ A/B}^{3/2}$ for $\varphi_{col} = 0.2 \varphi_a$.

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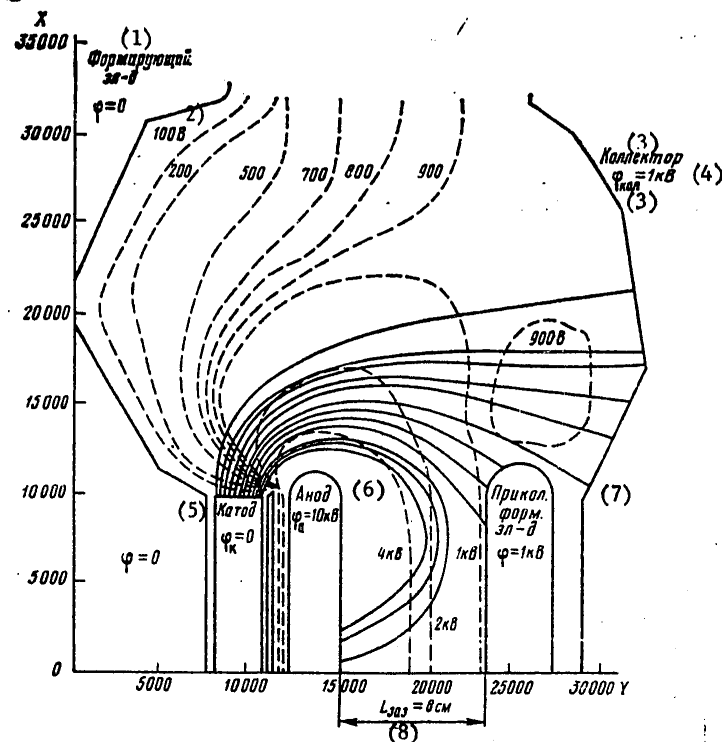


Figure 3. Results of the Computation of the EOS on an Electronic Digital Computer. Solid curves -- trajectories of the stream tubes; dashed curves -- equipotentials. OY -- rotation axis.

Key: 1. Forming electrode 5. Cathode
 2. V 6. Anode
 3. Collector 7. Forming electrode near collector
 4. kV 8. Gap

Calculations indicate that, as the retardation depth ϕ_a / ϕ_{col} increases, the structure of the field near the collector changes. The distribution of the field near the collector in the EOS with TSEF with a lowered potential of the collector is characterized by the presence in the vicinity of the collector of a large potential decline zone -- potential minimum [1,2]. The role of this minimum consists in delaying secondary electrons leaving the open collector surface. Without this potential trap, secondary electrons would get into the accelerating field and would move toward the anode.

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During the retardation $\varphi_a / \varphi_{col} = 5$ (Figure 2), the minimum of the potential in the system's zone near the collector has the form of a ravine with a potential gradient perpendicular to the trajectories of the electrons. This distribution of the field in the beam ensures the withdrawal of the forming ions from the beam in the direction of the forming electrode (6).

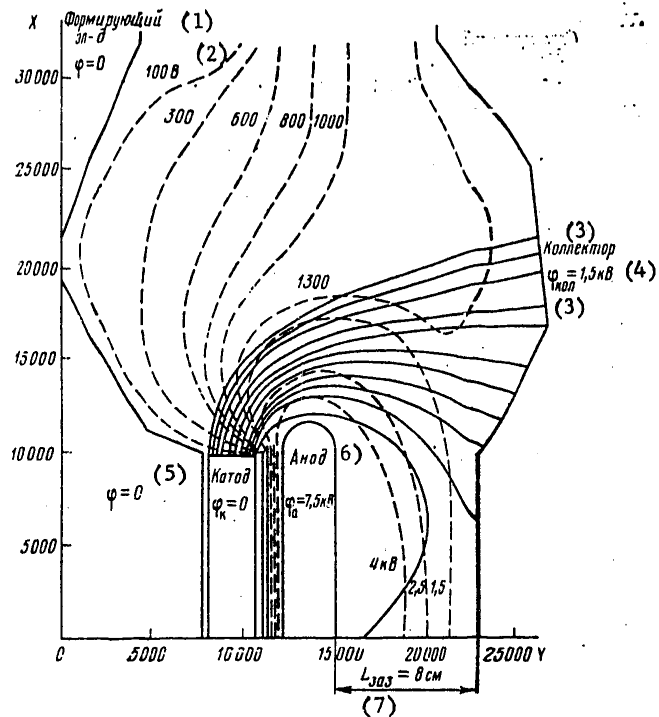


Figure 4. Results of the Calculation of a Modified EOS on an Electronic Digital Computer. Solid curves -- trajectories of the stream tubes; dashed curves -- equipotentials. OY -- rotation axis.

Key: 1. Forming electrode
2. V
3. Collector
4. kV
5. Cathode
6. Anode
7. Gap

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Further decrease in the collector potential $\varphi_a / \varphi_{col} = 10$ leads to the closing of the equipotentials in the zone of the minimum $\varphi_{min} = 0.9 \varphi_{col}$. Some of the stream tubes do not pass to the collector. The calculated passage of current under such conditions is $I_{col} = 85\% I_{cath}$. However, the collector perveance increases sharply: $P_{col} = 680 \cdot 10^{-6} A/B^{3/2}$.

The EOS without a forming electrode near the collector shown in Figure 4 is a modification of the electron-optical system for an electron-beam switch described above. It is a somewhat simplified design of an EOS with TsEF with the same high-voltage gap $L_{gap} = 8$ cm. At $\varphi_a / \varphi_{col} = 5$, more than 95% of the cathode current passes onto the collector. The minimum of the potential in the vicinity of the collector is formed in the shape of a ravine with a "run-off" of ions. The perveance of the system calculated by the collector voltage is $P_{col} = 345 \cdot 10^{-6} A/B^{3/2}$.

The minimum value of the negative cutoff voltage ensuring a total cutoff of the current during the delivery of the amplitude of the switched voltage to the collector was determined by calculations for the EOS shown in Figure 2. The device was cut off when collector received $U_{switched} = 200$ kV and the anode, modulator, and forming electrodes near the cathode received $U_{mod} = -10$ kV. The maximum intensity of the electric field was near the anode, being less than 5 kV/mm, which is a quite acceptable value.

In our opinion, the above calculations of an axially symmetric EOS with TsEF with a deep retardation of electrons indicate that it is promising to use systems of this kind in powerful electron-beam switches with energy recuperation.

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PUBLICATIONS, INCLUDING COLLECTIONS OF ABSTRACTS

NEW ELECTRIC CONTROL AND AUTOMATION EQUIPMENT DESCRIBED

Moscow TRUDY MOSKOVSKOGO ORDENA LENINA ENERGETICHESKOGO INSTITUTA: TEMATICHESKIY SBORNIK. ELEKTRICHESKIYE APPARATY UPRAVLENIYA I AVOTMATIKI (Works of the Moscow Order of Lenin Power Engineering Institute: Subject Collection. Electric Control and Automation Equipment) in Russian Issue 423, 1979, signed to press 15 Oct 1979 pp 2, 71-72

[Annotation and table of contents from book, M. Sh. Kulakhmetova responsible editor, MEI Rotaprint, 300 copies, 72 pages]

[Text] The results of research and developments in contact and contactless control and automation equipment performed at the Moscow Power Engineering Institute's Department of Electric Equipment Building.

These results pertain to the following areas:

- research and development of non-arcing contact equipment;
- research on equipment with hermetically sealed contacts;
- use of digital computers for calculation and study of the processes within the equipment and their characteristics;
- equipment with liquid metal contacts;
- study of the operating conditions of switching systems in various environments;
- contactless electrical equipment;
- a number of general theoretical questions in the area of electrical equipment.

The broad range of questions encompassed in the articles holds interest for specialists and investigators working in various areas of electrical equipment: electromagnetic devices, switching apparatuses for controlling various pieces of electrical equipment, automation and relay protection equipment, etc. Many of the questions set forth in the articles may also be used by specialists from a number of applied areas of electrical engineering related to the equipment.

The mathematical relationships presented in the collection, as well as information on new and prospective switching equipment and elements will be useful for developers and scientific workers whose activity is associated with the creation of new electrical equipment.

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CONTENTS	Page
Tayev, I. S., Akimov, Ye. G. Certain results of experimental electromagnetic synchronous a.c. contact research.....	3
Tayev, I. S., Mel'nichuk, V. N., Gorshkov, Yu. E. Calculation of arc entry time in an arc-arresting grid.....	6
Bul', B. K., Slukin, A. M. Reducing the noise level of a hercon by filling it with a dielectric liquid.....	10
Godzhello, A. G., Sokolov, V. P. Accuracy appraisals while controlling instantaneous values of functionally associated data.....	13
Shoffa, V. N., Galteyeva, Ye. F., Shibanov, V. K. Analysis of the distribution of the magnetic field of a gesakon [sic].....	16
Godzhello, A. G. Analysis of exponential nonlinear characteristics from the viewpoint of dimensionality theory and similarity theory.....	21
Puchkov, A. S., Chicheryukin, V. N. Development of relay designs with liquid metal contacts.....	24
Makarychev, Yu. M., Ryzhov, S. Yu., Kuzhekin, I. I. Methodology for measuring static pulling characteristics of electromagnets.....	28
Kovalevskiy, I. I., Izotov, A. Z. Study of an electromagnetic vibrating conductor using an electron model.....	33
Shoffa, V. N., Shibanov, V. K., Ragulin, I. A. Calculating the working point displacement in a permanent magnet in the directional commutator on a hercon.....	37
Degtyar', V. G., Ivanov, A. V. Principles for building high-current liquid metal switching devices.....	42
Korobkov, Yu. S. Dynamic characteristics of ferride activation.....	45
Degtyar', V. G., Vechkis, V. V. Dependence of the conductivity of a liquid metal contact on the contact area.....	49
Dil'dina, T. N. Volt-ampere characteristic of an arc in liquid at greater than atmospheric pressure and the conditions for its breaking.....	53

FOR OFFICIAL USE ONLY

Azanov, V. A., Frenkel', A. G., Yalovenko, V. Ye. A contact-less slip ring.....	55
Shopets, L. V., Solodovnikov, V. N. A contactless synchronous commutator-distributor.....	58
Bul', B. K., Nikolayev, N. N. Polyakov, Studying a sealed contact assembly with prestressed contacts.....	60
Shibanov, V. K. Calculation of the external field of magnetics with constant magnetization and with variable magnetization along their length.....	64
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9194
CSO: 1860

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NEW ELECTRONIC ENGINEERING MATERIALS AND DEVICES PRESENTED

Moscow TRUDY MOSKOVSKOGO ORDENA LENINA ENERGETICHESKOGO INSTITUTA: TEMATICHESKIY SBORNIK. MATERIALY I PRIBORY ELEKTRONNOY TEKHNIKI (Works of the Moscow Order of Lenin Power Engineering Institute: Subject Collection. Electronic Engineering Materials and Devices) in Russian Issue 403, 1979, signed to press 19 June 1979 pp 2, 69-70

[Annotation and table of contents from book, M. Sh. Antipova responsible editor, MEI Rotaprint, 400 copies, 70 pages]

[Text] The articles included in the collection are devoted to questions of modern electronic engineering and may be divided into 3 groups according to the nature of the questions being examined. The first group concerns articles of a theoretical nature which deal mainly with calculations of qualitative parameters of processes under study in actual and idealized physical environments and the determination of electronic device characteristics. The second group of articles includes theoretical research directed toward the search for the possibilities of improving characteristics and parameters of actual electronic devices on the whole or of their assemblies. The third group unites experimental and theoretical articles devoted to research on the properties of several known materials which are of interest for the creation of electronic and semiconductor devices as well as for development of the methods and equipment with which the indicated research was performed.

CONTENTS	PAGE
Shapochkin, M. B. Apparatus for measurement of excitation cross sections of the ion states of alkali metals using an intersecting beam method.....	3
Lebedev, A. K. On plane electromagnetic wave amplification during forced retarding processes.....	5
Lebedev, A. K., Reshetin, Ye. F. Parameter of non-linear amplification coefficient decomposition during retarding processes.....	10

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

Dimov, I. Calculating the breakdown voltage of fluorescent lamps with a conducting coating given constant voltage.....	12
Dimov, I. Townsend's first ionization coefficient in an argon-mercury mixture.....	15
Savenkov, V. I. Visibility range with artificial illumination in an optically transparent aqueous medium.....	18
Savenkov, V. I., Mazanov, V. G., Mel'nikov, G. A. Illumination intensity from an underwater searchlight.....	23
Mazanov, V. G., Savenkov, V. I., Andrianov, Ye. V. On determining the orthogonal projections of a light vector in the field of an inclined linear light source.....	27
Lebedkova, S. M., Petrikova, L. A. Improving color reproduction of fluorescent lamps for residential rooms.....	30
Pechenkin, V. I., Makarovskaya, O. Ya. Using an approximated mathematical model of a visual analyzer to calculate the number of brilliance gradations transmitted by a television picture tube.....	33
Kalyabina, I. A., Agafonova, Ye. D., Yerzunov, A. I., Likhacheva, N. I., Belavina, L. A., Gonzhalov, N. N., Anisimov, N. S. Study of gas evolution of photoelectron device coatings in a vacuum.....	36
Shitov, V. A. A rectifier based on fully controlled valves.....	40
Shevchenko, A. G. Operating modes and peculiarities in the design of transformers for stabilized converters.....	43
Zharikova, T. N. On expanding the regulation range of a converter cell.....	46
Varlashov, I. B., Sobolev, N. V., Lipko, G. T. The influence of non-uniformities on a calculation of the density of surface states in MDP metal-insulator-semiconductor structures.....	50
Suvorinov, A. V., Mukhina, O. B., Yamshchikova, I. V. Prospects for using thin layers of certain narrow zone semiconductors for creating Hall pickups.....	53
Borovov, G. I., Gorodovaya, T. I. The influence of heat treatment on the electrical properties of switching materials.....	57

FOR OFFICIAL USE ONLY

Kutepova, V. P. Dependence of the ultraviolet luminescence
of zinc oxide powders on excitation intensity..... 60

Mironenko, L. S., Yevmenenko, V. A. Electrical and luminescent
properties of GaN-irradiating structures..... 63

Boroshneva, T. V. Optical properties of cuprous chloride..... 67

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[239-9194]

9194
CSO: 1860

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NEW USES FOR STRONG ELECTRIC FIELDS IN TECHNOLOGY

Moscow TRUDY MOSKOVSKOGO ORDENA LENINA ENERGETICHESKOGO INSTITUTA: TEMATICHESKIY SBORNIK. ISPOL'ZOVANIYE SIL'NYKH ELEKTRICHESKIKH POLEY V TEKHNologii (Works of the Moscow Order of Lenin Power Engineering Institute: Subject Collection. Using Strong Electric Fields in Technology) in Russian Issue 417, 1979, signed to press 16 November 1979 pp 2, 103-104

[Annotation and table of contents from book, M. Sh. Kulakhmetova responsible editor, MEI Rotaprint, 500 copies, 104 pages]

[Text] Articles by associates and students of the Department of High Voltage Engineering of the Faculty of Electric Power Engineering, the Department of Electric Materials and Cables of the Electromechanical Faculty and the Department of Electrothermal Installations of the Faculty of Electrification and Automation of Industry and Transport are presented in this collection.

Diverse aspects of using strong electric fields in manufacturing processes, for example during electric spraying of polymer coatings, and questions concerning the active effect on atmospheric processes are examined in the articles.

A number of articles is devoted to analysis of the dangerous phenomena of static electricity and methods for controlling it.

Along with the indicated questions, problems concerning the development of high-voltage semiconductor devices and parametric current sources are examined in the collection.

Publication of this subject collection is conditioned by the importance and the urgency of the task of developing methods for the direct exposure of a material to an electrical field, by-passing the stage of intervening energy conversion from one form to another. As applicable to manufacturing processes, this method of exposure permits us to create fundamentally new, highly efficient manufacturing processes.

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CONTENTS	PAGE
Morozov, V. S., Styrikovich, I. M., Stepanyuk, N. G. Criterion for the effectiveness of methods for active effect on a thundercloud.....	3
Kovalev, V. D., Mirzabekyan, G. Z., Krivov, S. A., Petrov, S. A., Petukhov, V. S. On dispersing warm fogs.....	5
Kovalev, V. D., Mirzabekyan, G. Z. On the question of ion discharge of fog droplets.....	8
Kovalev, V. D., Mirzabekyan, G. Z., Morozova, T. K. Discharging fog droplets using submicron particles.....	11
Basiyev, T. S., Vereshchagin, I. P., Makal'skiy, L. M. A charged aerosol generator.....	14
Makal'skiy, L. M. A charged paraffin particle generator.....	17
Glatenok, I. V., Zharkov, Yu. V. Statistical calculation of the energy in a spark gap during a discharge of static electricity.....	20
Lossiyevskaya, T. V., Maksimov, B. K., Tikhonov, A. V. Towards a calculation of safe conditions for filling storage tanks with electrified petroleum products.....	23
Maksimov, B. K., Obukh, A. A. Statistical evaluation of the danger of static electricity discharges.....	27
Panyushkin, V. V., Pashin, M. M. Efficiency of the operation of various types of sprayers.....	31
Merkind, Z. I., Pashin, M. M., Titova, G. M. Dispersity of powder polymer materials used for spraying in an electric field.....	34
Pashin, M. M., Titova, G. M. Effect of the dispersity of powder materials on the effectiveness of spraying groove insulation in an electric field.....	40
Lyubskiy, A. S., Pashin, M. M. Spraying groove insulation of electric machinery using electrostatic sprayers.....	44

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

Vereshchagin, I. P., Morozov, V. S. The charge of non-conducting aspherical particles in a corona discharge field.....	47
Stepanov, G. P., Monakhov, A. F., Filippenko, L. L. Modeling the manufacturing processes for the electrochemical metal plating of high-voltage silicon structures.....	53
Stepanov, G. P., Monakhov, A. F. Using a method for profiling electrode surfaces to create power semiconductor devices with a working voltage of more than 10 kV.....	58
Zaytsev, Yu. V., Roshchina, I. A., Krok, F. S., Kolmakova, L. A., Polymerization of a conducting suspension based on E-40 epoxy resin in an electric field.....	62
Shirinskaya, N. N., Chernov, V. L., Vysotskiy, A. F., Kolmakova, L. A., Zaytsev, Yu. V. Using an electric field to spray resistive material while creating resistive elements.....	66
Slesarev, Yu. A. Means for stabilizing the crucibleless electron zonal melt process.....	69
Pechorkin, V. V. Mathematical modeling of a parametric current source with key current setting regulators.....	76
Gutterman, K. D., Ashinyants, S. A. Using an EOMN-2000 transformer in parametric current source circuits.....	81
Tsyganov, Yu. P., Panin, Ye. P., Zhigalko, Ye. K. Selection of optimum modes during magnetic pulse compression of metal compounds.....	86
Lossiyevskaya, T. V., Maksimov, B. K., Tikhonov, A. V. The electric field in a cylindrical storage tank partially filled with an electrified liquid, considering the effect of the inlet pipe.....	91
Vereshchagin, I. P., Salikhova, N. R., Fedprov, Yu. S. Calculating a field with a volumetric charge using a finite elements method.....	94

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[240-9194]

9194
CSO: 1860

- END -